CHAPTER 2

HARBOR STUDIES AND SURVEYS

IMPORTANCE OF HISTORICAL INFORMATION

Until recently, scientific design criteria for shore protection developed slowly. Long trial and error expedience led to structures best suited to local conditions. Engineers had to experiment to find a suitable protected site long enough for an inner harbor without the rapid shoaling of channel approaches. The history of early structures and construction methods is practical background for new construction.

ENGINEERING DESIGN

Wherever possible, standard designs can save time in design, construction, and maintenance. Standard designs and bills of material allow advance procurement of materials and equipment. Using them requires a knowledge of the site and the existing foundation. Reconnaissance, construction surveys, soil bearing tests, driving of test piles, and sieve analyses of local sands and gravels precede final design. Engineers design nonstandard expedient structures only when they cannot use standard designs.

RESPONSIBILITY FOR HYDROGRAPHIC SURVEYS

The mapping organization in the TO follows policies set by the G2. The theater engineer coordinates the work of the topographic units in carrying out policy. The theater engineer also coordinates the work of all topographic units of subordinate commands. The unit engineer plans and executes work needed by a particular unit that is not included in the theater mapping program. The engineer includes special maps and map overlays. His topographic units make astrofixes for map control and to tie into the existing triangulation system. Construction units establish azimuth and some vertical control for assigned construction jobs.

HYDROGRAPHIC SURVEY METHODS

Technical Manual (TM) 5-235 describes military equipment and methods of taking and locating soundings. Specific information includes--

a. Factors considered in hydrographic surveys. To locate a wharf site, the engineer must determine the submerged relief at the proposed site.

(1) Water depth. Water depth is critical to the operation of ships and craft. Engineers must obtain bathymetric measurements in the port area and seaward approaches to the facilities. The normal draft for a container ship is approximately 40 feet.

(2) Bottom character. Engineers must study the character of the bottom. They must locate and remove or mark foreign and random objects, including boulders, oil drums, and ship wreckage.

(3) Tidal characteristics. Tidal parameters that require determination are heights, range intervals, times, and behavior of tidal currents on a daily and seasonal basis and during storms. Daily tidal ranges exceed 20 feet.

(4) Discharge volumes and river flow velocity. These factors affect traffic regulation, structure location and orientation, sediment transport and deposition, and dredging.

(5) Extent, duration, and causes of inland flooding. Harbor routine may vary during flood seasons. Sediment introduced in harbor areas may create navigation problems. Historical data helps accurate forecasting.

(6) Tidal and river currents. Current direction and velocity affect navigation. There are longshore currents, wind currents, river currents, and permanent great currents. Several currents may act together.

(7) Shoreline data. Shore tidal conditions must be established for daily, seasonal, and extreme tide stages.

(8) Location of landmarks as navigational aids. Hydrographic and topographic maps and aerial photography simplify locating landmarks. Field checks ensure acceptable visibility.

(9) Location of current and abandoned structures in the water and along shore margins.

(10) Sub-bottom characteristics. These include sediments, layering, bearing capacities, and consolidation.

b. Types of surveys. To obtain the required information, engineers make the following separte surveys:

(1) Construction planning survey. Establishes basic facts of shoreline, water depth, bottom character, and existing structures.

(2) Special detail survey. Serves specific projects of construction or rehabilitation.

(3) Survey of operating harbors. Obtains data on channel characteristics, aids and hazards to navigation, wharf location, and harbor structures.

c. Methods of hydrographic survey.

(1) Contemporary. Methods depend on type of data required, equipment of the team making the survey, area to cover, and character of the body of water being surveyed.

(2) Sounding methods. Engineers make and plot soundings to ensure proposed wharf locations have adequate depth. TM 5-235 describes current Tables of Organization and Equipment (TOE) equipment for sounding operations. It includes automatic depth recorders, sounding poles (to 2 fathoms), leadlines (more than 2 fathoms), sweeps and drags, special survey vessels, buoy markers, signals (tripods, pylons) set up ashore, sextants, and others. Recording tide heights is a standard process, but soundings make recording easier. Depths measured and recorded below the water level are corrected on charts of the location.

METHODS OF SWEEPING TO LOCATE OBSTRUCTIONS

a. Sweeping locates pinnacles or other navigation obstacles above the draft limits required for the largest ships to use the area. Sweeping is always used as a final check after dredging. Sweeping is discussed in TM 5-235.

b. Methods of sweeping.

(1) Leadlines. Leadlines indicate the depth in waterways with regular bottoms. They cannot reliably show minimum depth over rock pinnacles, sunken wrecks, or other dangers.

(2) Wire drag. The wire drag is a horizontal bottom-wire. It is supported by adjustable upright cables suspended from surface buoys. The upright cables can be adjusted to sweep at a given depth. They make adjustments for the rise and fall of the tide. They hang nearly vertical with weights at their lower end. The drag wire is kept from sagging by several intermediate wooden floats attached to the wire. The drag wire, which may be 5 miles long, is towed by two launches. A buoy is placed over each obstruction located, then the drag is cleared. A small sounding boat makes careful soundings in the buoyed area to find the minimum depth over the obstruction.

(3) Wire sweep. The wire sweep is a modification of the wire drag. Buoys are placed farther apart. The wire sweep cannot vary the depth of the wire while dragging. It cannot prevent sag of the wire between buoys. It can be put in operation quicker than the drag. It is used in areas with few obstructions and with water deeper than required for navigation.

(4) Sweep bar. Surveyors use sweep bars to determine minimum clear depths. They locate obstructions and navigation dangers in confined areas, such as shoals, rock pinnacles, reefs, or wrecks. The sweep bar is a heavy section of railroad rail, steel pipe, or a structural steel section. It is held by two vertical cables. It can be suspended from a float, catamaran, or boat of suitable size. The suspending craft may be either towed or self-propelled. It must maneuver to maintain horizontal sweeping control. The sweep bar is suspended to avoid sag or deflection. The supporting craft can control depth by adjusting the cables holding the bar. Sweep bars have wide applications. They range from small hand sweeps operated from a rowboat for locating minor obstructions to specially-designed crafts for sweeping large channels and harbors.

(5) Specialized sweeping. Naval units are required when sweeping for mines.

METHODS OF BOTTOM INVESTIGATION

a. Types and uses.

(1) Underwater investigations of bottom materials are made from wash borings, core borings, probing, and diving.

(2) A hydrographic survey includes superficial bottom examination based on materials that adhere to grease kept in a cup-shaped depression in the bottom of the sounding lead.

(3) Investigations of bottom materials are made to--

* Indicate the probable length and size of adequate bearing

* Establish the most suitable pile material.

* Determine the type and depth of dredging or type of dredging equipment to use.

b. Wash borings.

(1) The bottom material must be soft enough so a casing pipe can penetrate it. The casing is driven into the bottom, a few feet at a time. A hollow drill rod is inserted in the casing. The nozzle at the lower end of the drill rod usually has a chisel point for boring. Water is washed down the rod as it is raised and lowered in the casing. Water and bottom material are forced to the surface between the casing and the rod. This overflow is discharged into a bucket. Suspended material is allowed to settle for analysis.

(2) To obtain a dry sample, the drill is removed. In its place, a short length of sample pipe is attached to the rod. The rod is placed in the casing and driven a foot or more into the bottom to force a sample of material into the sample pipe. The casing stands in place until the rod and sample pipe are removed with the dry sample.

c. Core borings. Core drilling is necessary for rock stratum and for soils containing clay or clay with boulders. A casing is driven through the overlying soil to its limit of penetration. Materials within the casing are then removed. Rotary-drill coring equipment is then inserted into the casing to remove the core.

d. Probing. Probing serves mainly to determine the depth to the surface of rock or hardpan. It obtains bottom materials and tests bottom hardness. Lengths of pipe are forced into soft bottom materials by hand or are driven with a maul.

e. Diving. Usually divers investigate underwater piling and other foundations or obstructions.

TIDES AND TIDAL CURRENTS

Tides have a variety of effects on port construction (see TM 5-235). Tidal currents are the alternating horizontal movements of water associated with the rise and fall of the tide. They are caused by astronomical forces.

a. Information. The Naval Oceanographic Office, Washington, D. C., maintains files of hydrographic charts for areas throughout the world, exclusive of the U.S. The office also prepares tide tables and other hydrographic data, which are available upon request. Lists and publications include sailing directions, lists of lights, radio weather and navigational aids, current atlases, fleet guides, marine geographies, surface temperature charts, tide tables, tidal current tables, general navigation charts, and coastal hydrographic charts. Information about the coastal waters of the U.S. and its possessions is published in detail by the National Ocean Survey (formerly Coast and Geodetic Survey), U.S. Department of Commerce. Winds or river discharge may cause currents to vary from predictions by as much as half an hour in well-documented areas. In poorly documented areas, variation may be greater.

b. Effects of tidal waves by type.

(1) Progressive. A progressive wave leads to maximum current flow near high and low tides. The rate of progress of the rest of the tidal wave is much greater than the speed of the current. For example, the crest of the tidal wave in the Hudson River advances at a rate of about 16 knots; however, the average maximum rate of the tidal current is less than 2 knots.

(2) Stationary. Oscillation of the water in the basin leads to maximum current flow at half tide. Strength of current is greatest at the axis of oscillation. It decreases as it approaches the end of the basin, where the range of the tide is greatest.

TIDAL PRISM

The tidal prism is the total amount of water flowing into a harbor or estuary or out again with movement of the tide. It excludes any freshwater flow. The tidal prism may be estimated by measuring the volume of the area or the volume of flow through the harbor entrances. Changes in the tidal prism and restrictions of the waterways may change the depth or direction of existing channels. These changes happen through scour or sedimentation. Such changes are difficult to predict or evaluate. Constructing pile structures, where practical, can avoid changes in the tidal prism.

WAVES

The familiar ocean waves are wind waves generated by winds blowing over water. They range in size from ripples on small bodies of water to large ocean waves as high as 100 feet. Wind waves cause most of the damage to ocean coasts. At sea or near the shore, the most noticeable waves are often swell associated with winds over great distance. Another type of wave, the tsunami, is created by earthquakes or other tectonic disturbances on the ocean floor. Tsunamis have caused spectacular damage at times. Fortunately, tsunamis occur infrequently.

a. Wave characteristics. Wind waves are known as oscillatory waves. They are defined by height, length, and period.

(1) Definition of wave terms. Wave height is the vertical distance from the top of the crest to the bottom of the trough. Wave length is the horizontal distance between successive crests. Wave period is the time between successive crests passing a given point.

(2) Determination of wave characteristics. Four variables determine the height, length, and period of wind waves--

* Fetch, or the distance the wind blows over the sea in generating the waves.
* Wind speed.
* Length of time the wind blows.
* Decay distance, or distance the wave travels after leaving the generating area.

Generally, the longer the fetch, the stronger the wind. The longer the wind blows, the larger the waves. If shallow enough, the water depth affects the size of wave generated.

b. Wave classifications. A description of a wave involves both its surface form and the fluid motion beneath it. A wave describable in simple mathematical terms is called a simple wave. Complex waves have several components and are difficult to describe in form and motion. Other classifications include oscillatory or nearly oscillatory waves. In these, water particle motion is described by orbits which are closed or nearly closed for each wave period. The type of wave most important to port construction and rehabilitation is the gravity wave. Gravity is the principal restoring force. Gravity waves are further classified as deep water, transitional, or shallow-water waves.

c. Deep-water waves. Deep-water waves are at a water depth more than one-half the wave length or when d/L (Figure 2-1) exceeds one-half. The phase velocity is the length of the wave divided by the time required to travel this length. It is an important characteristic of wave motion.

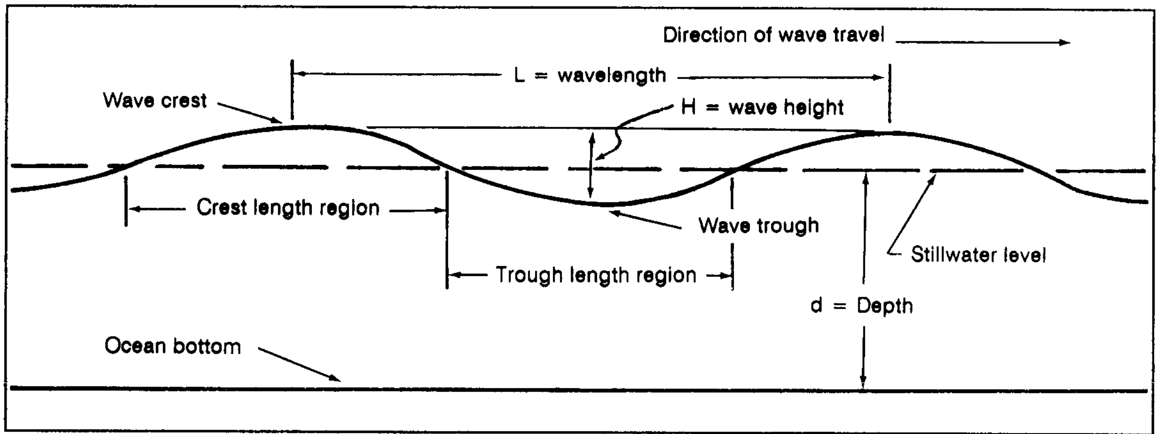

Figure 2-1. Deep-Water Wave

WAVE ENERGY AND ACTION

a. Energy content of waves. The total energy of a wave system is the sum of its kinetic energy and its potential energy. The kinetic energy is that part of the total energy due to water particle velocities associated with wave motion. Potential energy is the energy resulting from the part of the fluid mass above the trough. According to the Airy (first-order) theory, potential energy may be determined relative to mean water level. All waves may be propagated in the same direction. Potential and kinetic energy components may be equal. Under these conditions, the total wave energy (E) is one wave length per unit crest width, as given by Equation 1.

$$E = E_k + E_p = \frac{pg\,H2L}{16} + \frac{pgH2L}{16} = \frac{pgHL}{8} \qquad \text{(Equation 1)}$$

where:

E_k = kinetic energy
E_p = potential energy
P = mass density = w/g (w = unit weight) = $\frac{2.0\text{ lb-sec2}}{4\text{ft}}$ (slugs/ft^3) for salt water
g = gravitational acceleration
H = wave height
L = wave length

Substituting p = 2.0 slugs/ft^3, the equation can be reduced to a proximately $E = 8LH^2$. This equation indicates a wave 12 feet high and 1,300 feet long with an energy content of nearly 1,500,000 foot- pounds per foot of wave length. Dynamometer readings on breakwaters exposed to the direct force of waves show wave pressures as high as 7,000 pounds per square foot. These are maximum readings over an area of about 1 square foot. It is improable that equally great pressures are experienced over the total area of a bulkhead or break water.

b. Forces exerted by a blocked wave. When a wave is suddenly stopped by an obstacle, it generates the following forces, which act alone and together on the obstacle:

(1) Direct horizontal force combining impact and continued pressure. A breakwater with a constant water level on the sheltered side feels pressure on the exposed side. One end of fluctuation is the result of a positive combined pressure from the kinetic energy of the moving water and the static head of the wave at maximum height. The other end is a negative pressure when the trough of the wave is at the breakwater.

(2) Deflected vertical force upward.

(3) Vertical downward force resulting from the collapse of the wave.

(4) Downward kinetic and static pressure on top of the structure.

(5) Suction from the backwash, which tends to produce negative pressure inside the structure

c. Height of rise of a blocked wave. The energy content of a wave is equally divided. One part is the kinetic energy of the moving particles of water. The other is the potential energy of the mass of water raised above still water level. A wave may encounter a vertical obstruction in water greater thsn its breaker depth. The kinetic energy of the moving particies is then largely converted to potential energy. The wave rises to nearly twice its normal height. This fact is important in the design of structures in water with a depth eater than breaker depth because it permits calculating the maximum height needed to keep waves from breaking over the top.

d. Effect of wave action on a structure. Waves have many effects on natural and man-made coastal features. The tremendous wave forces generated by a storm make damage likely. The forces exerted by a blocked wave may cause the following effects on obstacles:

(1) Vibration or weaving, which tends to weaken connections.

(2) Hydrostatic pressure or suction in all directions in the joints and interstices.

(3) Alternate compression and expansion of volumes of air in cavities, which transmit pressure to internal parts.

(4) Deflected vertical force, which tends to shear off projections beyond the face line of a structure.

(5) Direct horizontal force of impact and continued pressure, which tends to overturn or slide.

e. Battering -ram action of floating objects. The energy of a wave is contrated as a battering ram when it hurls a floating object.